Solar Thermal Power Technology

Prof. Gopal Chaudhari
(M.E. Electrical)
(Assi. Prof. Electronics Engineering
YTIET, Bhivpuri Road, Karjat,
Mumbai University)

Prof. Sharvari Sane
(M. Tech Electrical)
(H.O.D. Electrical Engineering
SESGOIFE, DIKSAL, Karjat,
Mumbai University)

Ms. Jyoti Sanjay Bharati
Power Plant Engineering & Energy Management
SESGOIFOE
DIKSAL,KARJAT
e-mail:bharatijyot@gmail.com

Ms. Gulrez Aslam Bodhle
Power Plant Engineering & Energy Management
SESGOIFOE
DIKSAL,KARJAT
e-mail: gul24oct@gmail.com

Abstract**—** Generally energy is available in two forms i.e. non renewable and renewable energy sources. Several environmental issues are related with the use of conventional energy sources like coal, petroleum and natural gas and different type of advantages or benefits offered by non conventional energy sources like solar, wind and small hydro included. Solar technology from history point of view is very old i.e. from 7th century B.C. to today. But in recent years the attention is more focused on solar energy for generate electricity. Solar energy help us to reduce the use of fossil fuel. Solar technology is a pollution free technology, so this technology is called by green technology. Solar energy can be used in two ways one of which is solar photovoltaic and another one is solar thermal and this paper is based on the review of solar thermal energy.

Keywords*- solar energy; solar thermal power generation; parabolic trough.*

*****

I. INTRODUCTION

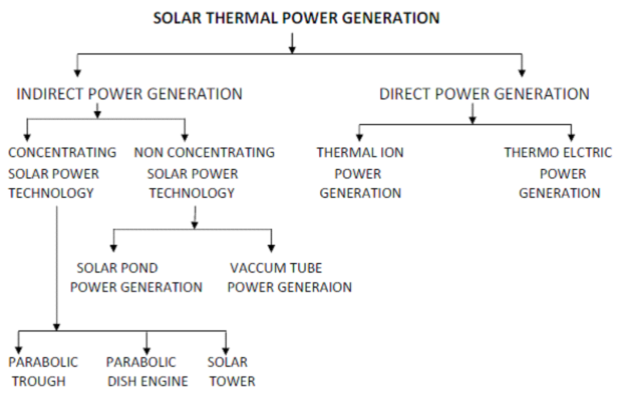
Energy is very important factor in economic development and generation of wealth by generation of electricity with use of energy. Fossil fuel are in limited quantity on the earth and there are many environment pollution problem with the use of the fossil fuel so there is very important to use renewable energy sources to generate power for fulfill the need of world. In solar technology solar thermal power system which is used for electricity generation which is known by the solar thermal electricity generation system. This paper discuss the history of solar thermal developments and their current status and in India what type of opportunities and challenges for solar thermal power generation plant also discussed.

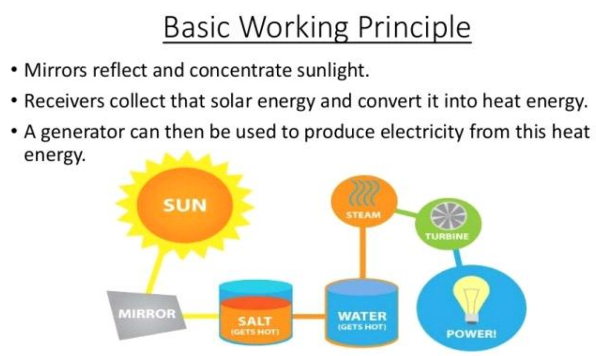
II. CLASSIFICATION AND PRINCIPLE

In view of problems associated with conventional energy sources, the focus is now shifting to conservation of energy, and to the search for renewable sources of energy that are also environmentally benign. Solar thermal power generation or Solar Thermal Electricity (STE) generating systems are emerging renewable energy technologies. It can be developed as a viable option for electricity generation in future. Solar electricity is a clean and eco-friendly energy solution for Sustainable Energy. Solar thermal power is currently paving the way for the most cost-effective solar technology on a large scale and is heading to establish a cleaner, pollution free and secured future.

Photovoltaic **(**PV**)** and solar thermal technologies are two main ways of generating energy from the sun, which is considered the inexhaustible source of energy**.** PV converts sunlight directly into electricity whereas in Solar thermal technology, heat from the sun's rays is concentrated to heat a fluid, whose steam powers a generator that produces electricity. It is similar to the way fossil fuel-burning power plant work except that the steam is produced by the collected heat rather than from the combustion of fossil fuels. The most important technology of the solar thermal power generation is concentrating solar power (CSP) technology.

In CSP technology sun’s direct normal irradiation (DNI) is concentrated to produce large heat at a high temperature. This heat is used to produce electricity by the conventional steam cycle. The heat resource of solar thermal power generation is solar radiation. So how to collect more solar radiation is one of the key technologies the classification of solar thermal power generation.





The CSP can be classified as:

- Parabolic trough.
- Solar tower.
- Parabolic dish-engine.
- Linear Fresnel reflector.

1. Parabolic Trough

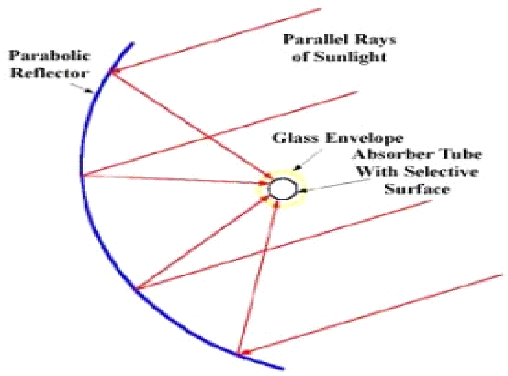


Figure-1.3 Parabolic trough

Parabolic trough power plants are line-focusing STE (solar thermal electric) power plants. Trough systems use the mirrored surface of a linear parabolic concentrator to focus direct solar radiation on an absorber pipe running along the focal line of the parabola. The HTF (heat transfer fluid) inside the absorber pipe is heated and pumped to the steam generator, which, in turn, is connected to a steam turbine. A natural gas burner is normally used to produce steam at times of insufficient insolation. The collectors rotate about horizontal north–south axes, an arrangement which results in slightly less energy incident on them over the year but favors summertime operation when peak power is needed.

The major components in the system are collectors, fluid transfer pumps, power generation system and the controls. This power generation system usually consists of a conventional Rankine cycle reheat turbine with feed water heaters deaerators, etc. and the condenser cooling water is cooled in forced draft cooling towers. These type of power plants can have energy storage system comprising these collectors usually have the energy storage facilities. Instead they are couple to natural gas fired back up systems.

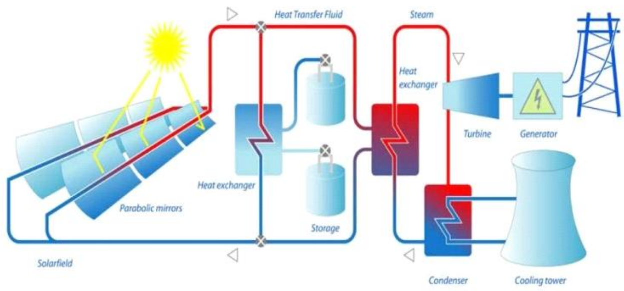


Figure-1.4 Strucure Parabolic trough

2. Solar Tower

In power tower systems, heliostats (A Heliostat is a device that tracks the movement of the sun which is used to orient a mirror of field of mirrors, throughout the day, to reflect sunlight onto a target-receiver) reflect and concentrate sunlight onto a central tower-mounted receiver where the energy is transferred to a HTF. This energy is then passed either to the storage or to power-conversion systems, which convert the thermal energy into electricity. Heliostat field, the heliostat controls, the receiver, the storage system, and the heat engine, which drives the generator, are the major components of the system.

For a large heliostat field a cylindrical receiver has advantages when used with Rankine cycle engines, particularly for radiation from heliostats at the far edges of the field. Cavity receivers with larger tower height to heliostat field area ratios are used for higher temperatures required for the operation of Brayton cycle turbines

ISSN: 2321-8169
146 – 151

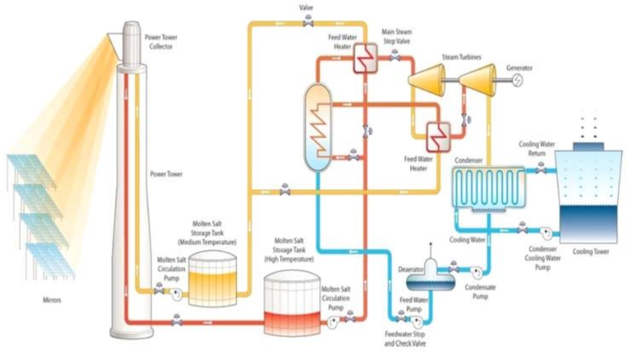


Figure-2.3 Solar tower

These plants are defined by the options chosen for a HTF, for the thermal storage medium and for the power-conversion cycle. HTF may be water/steam, molten nitrate salt, liquid metals or air and the thermal storage may be provided by PCM (phase change materials). Power tower systems usually achieves concentration ratios of 300–1500, can operate at temperatures up to 1500^{o} C. To maintain constant steam parameters even at varying solar irradiation, two methods can be used:

- Integration of a fossil back-up burner; or
- Utilization of a thermal storage as a buffer

By the use of thermal storage, the heat can be stored for few hours to allow electricity production during periods of peak need, even if the solar radiation is not available. The modern R&D efforts have focused on polymer reflectors and stretched-membrane heliostats. A stretched-membrane heliostat consists of a metal ring, across which two thin metal membranes are stretched. A focus control system adjusts the curvature of the front membrane, which is laminated with a silvered-polymer reflector, usually by adjusting the pressure in the plenum between the two membranes. Examples of heliostat based power plants were the 10 MWe Solar One and Solar Two demonstration projects in the Mojave Desert, which have now been decommissioned. The 15 MW Solar Tres Power Tower in Spain builds on these projects. In Spain the 11 MW PS10 Solar Power Tower was recently completed. In South Africa, a solar power plant is planned with 4000 to 5000 heliostat mirrors, each having an area of 140 m².

3. **Parabolic Dish-Engine System**

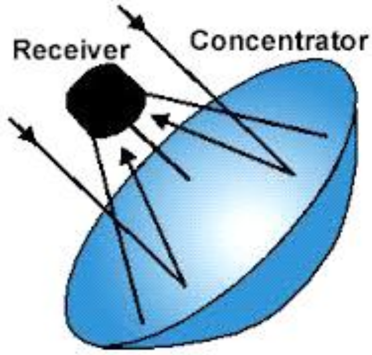


Figure-2.4 Parabolic dish system

The parabolic dish system uses a parabolic dish shaped mirror or a modular mirror system that approximates a parabola and incorporates two-axis tracking to focus the sunlight onto receivers located at the focal point of the dish, which absorbs the energy and converts it into thermal energy. This can be used directly as heat for thermal application or for power generation. The thermal energy can either be transported to a central generator for conversion, or it can be converted directly into electricity at a local generator coupled to the receiver.

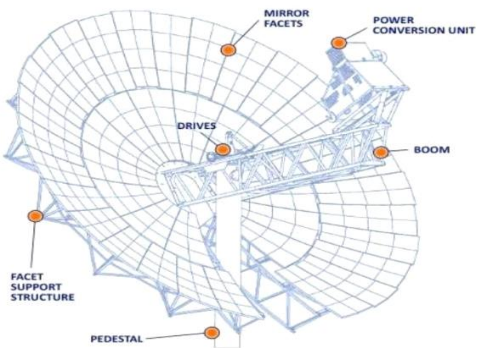


Figure-2.5 Parabolic dish structure diagram

The mirror system typically is made from a number of mirror facets, either glass or polymer mirror, or can consist of a single stretched membrane using a polymer mirror of thin metal stretched membrane.

The PDCs (parabolic dish collector) track the sun on two axes, and thus they are the most efficient collector systems. Their concentration ratios usually range from 600 to 2000, and they can achieve temperatures in excess of 1500^{o}C. Rankine-cycle engines, Brayton-cycle engines, and sodium-heat engines have been considered for systems using dish-mounted engines the greatest attention though was given to Sterling-engine systems.

The main challenge facing distributed-dish systems is developing a power-conversion unit, which would have low capital and maintenance costs, long life, high conversion efficiency, and the ability to operate automatically. Several different engines, such as gas turbines, reciprocating steam engines, and organic Rankine engines, have been explored, but in recent years, most attention has been focused on Sterling-cycle engines. These are externally heated piston engines in which heat is continuously added to a gas (normally hydrogen or helium at high pressure) that is contained in a closed system. The Sterling Energy Systems (SES) and Science Applications International Corporation (SAIC) dishes at UNLV and the Big Dish in Canberra, Australia are representatives of this technology.

4. Fresnel Linear Reflector

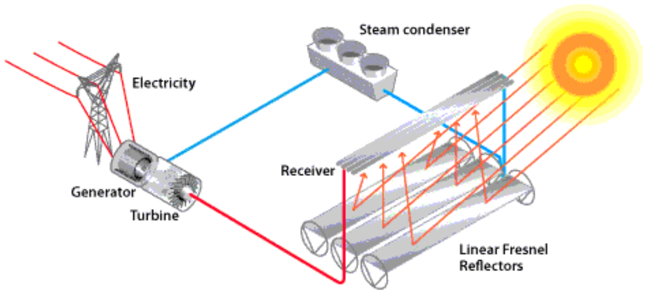


Figure-2.6 Fresnel linear reflector

The first linear Fresnel reflector was developed in Italy in 1961 by Giovanni Francia of the University of Genoa. Francia demonstrated that such a system could create elevated temperatures capable of making a fluid do work. The technology was further investigated by companies such as the FMC Corporation during the 1973 oil crisis, but remained relatively untouched until the early 1990s. In 1993, the first CLFR was developed at the University of Sydney in 1993 and patented in 1995. In 1999, the CLFR design was enhanced by the introduction of the advanced absorber. In 2003 the concept was extended to 3D geometry. Research published in 2010 showed that higher concentrations and / or higher acceptance angles could be obtained by using nonimaging optics to explore different degrees of freedom in the system such as varying the size and curvature of the heliostats, placing them at a varying height (on a wave-shape curve) and combining the resulting primary with nonimaging secondaries.

Linear Fresnel reflectors capture the sun's energy with large mirrors that reflect and focus the sunlight onto a linear receiver tube. The receiver contains a fluid that is heated by the sunlight and then used to create superheated steam that spins a turbine that drives a generator to produce electricity. Alternatively, steam can be generated directly in the solar field, which eliminates the need for costly heat exchangers.

Linear concentrating collector fields consist of a large number of collectors in parallel rows that are typically aligned in a north-south orientation to maximize annual and summer energy collection. With a single-axis sun-tracking system, this configuration enables the mirrors to track the sun from east to west during the day, which ensures that the sun reflects continuously onto the receiver tubes.

2.6 Comparison of Different CSP Technology

Technology	Temperature	Hybrid Operation	Cost $/KW	Efficiency	Focus	HTF
Parabolic Trough	400	Possible	4200	10-15	Line	Synthetic Oil
Solar Tower	1000	Possible	4500	14-17	Point	Molten Salt
Parabolic Dish	750	Still in R & D	6000	18-25	Point	Synthetic Oil
Fresnel Reflector	270	Possible	2200	9-15	Line	Steam

III. SOLAR THERMAL POWER GENERATION PROGRAM OF INDIA

In India the first Solar Thermal Power Plant of 50kW capacity has been installed by MNES following the parabolic trough collector technology (line focussing) at Gwalpahari, Gurgaon, which was commissioned in 1989 and operated till 1990, after which the plant was shut down due to lack of spares. The plant is being revived with development of components such as mirrors, tracking system etc. A Solar Thermal Power Plant of 140MW at Mathania in Rajasthan, has been proposed and sanctioned by the Government in Rajasthan. The project configuration of 140MW Integrated Solar Combined Cycle Power Plant involves a 35MW solar power generating system and a 105MW conventional power component and the GEF has approved a grant of US$ 40 million for the project. The Government of Germany has agreed to provide a soft loan of DM 116.8 million and a commercial loan of DM 133.2 million for the project. In addition a commercial power plant based on Solar Chimney technology was also studied in North-Western part of Rajasthan. The project was to be implemented in five stages.

In the 1st stage the power output shall be 1.75MW, which shall be enhanced to 35MW, 70MW, 126.3MW and 200MW in subsequent stages. The height of the solar chimney, which would initially be 300m, shall be increased gradually to 1000m. Cost of electricity through this plant is

ISSN: 2321-8169
146 – 151

expected to be Rs. 2.25 / kWh. However, due to security and other reasons the project was dropped. BHEL limited, an Indian company in power equipments manufacturing, had built a solar dish based power plant in 1990's as a part of research and development program of then the Ministry of Non-conventional Energy Sources. The project was partly funded by the US Government. Six dishes were used in this plant. Few states like Andhra Pardesh, Gujarat had prepared feasibility studies for solar thermal power plants in 1990's. However, not much work was carried out later on.

Opportunities for solar thermal power generation in India Solar thermal power generation can play a significant important role in meeting the demand supply gap for electricity. Three types of applications are possible 1. Rural electrification using solar dish collector technology 2. Typically these dishes care of 10 to 25 kW capacity each and use striling engine for power generation. These can be developed for village level distributed generation by hybridizing them with biomass gasifier for hot air generation. 3. Integration of solar thermal power plants with existing industries such as paper, dairy or sugar industry, which has cogeneration units. Many industries have steam turbine sets for cogneration. These can be coupled with solar thermal power plants. Typically these units are of 5 to 250 MW capacities and can be coupled with solar thermal power plants. This approach will reduce the capital investment on steam turbines and associated power-house infrastructure thus reducing the cost of generation of solar electricity 4. Integration of solar thermal power generation unit with existing coal thermal power plants. The study shows that savings of upto 24% is possible during periods of high insolation for feed water heating to 241 0C (4).

Barriers Solar thermal power plants need detailed feasibility study and technology identification along with proper solar radiation resource assessment. The current status of international technology and its availability and financial and commercial feasibility in the context of India is not clear. The delays in finalizing technology for Mathania plant have created a negative impression about the technology. Way ahead Solar thermal power generation technology is coming back as commercially viable technology in many parts of the world. India needs to take fresh initiative to assess the latest technology and its feasibility in the Indian context. These projects can avail benefits like CDM and considering the solar radiation levels in India the se plants can be commercially viable in near future. The MNRE and SEC (Solar Energy Center) should take initiative to study these technologies and develop feasibility reports for suitable applications. Leading research institutes such as TERI can take up these studies.

IV. OPPERTUNITIES AND PROGRAM DEVELOPMENT IN INDIA ON THE CONCEPT OF SOLAR THERMAL POWER GENERATION:

MNRE's first solar thermal power plant is of 50kw capacity is installed on the basis of parabolic trough collector technology at Gwalpahari, Gurgaon. Solar Thermal technology based power plant of 140MW at Mathania in Rajasthan is installed, Which has been proposed and sectioned by the government of Rajasthan. The project configuration of 140MW integrated solar combined cycle power plant which involves a 35MW solar power generating system and also a 105MW conventional power component are involved in this project. BHEL limited is an Indian company in power equipments
manufacturing and had built a solar dish based on the power plant in 1990's which is part of research and development program of MNRE. In this project six dishes used in this plant and was partially funded b y the US Government. There are several opportunities present in India for application of solar thermal power plant which generate power for meeting the demand of the electricity. some types of application are as possible which has been discussed below[8]: 1. Solar dish collector technology use for rural electrification. Dishes having a capacity of 10Kw to 25KW and use a sterling engine for power generation. 2. solar thermal power plants integration with existing industries such as paper, diary or sugar industry. Which has cogeneration units and many industries have steam turbine sets for cogeneration. These can be coupled with solar thermal power plants and these units have a capacity of 5 to 250MW capacities . this result will reduce the capital investment on the steam turbine and thus also reduce the cost of the solar electricity. 3. Solar thermal power unit can be integrated with the coal thermal power plants to produce electricity.

CONCLUSION

Today Solar thermal technology is commonly used for electricity production, which is one of the best option for meet the energy demand of developed and developing countries. In India developments in area of solar thermal are regularly going on. India has rich amount of solar energy as comparison to developed countries like US, Japan and Spain. In future India can meet the challenge of electricity generation according to the Indian population requirement with the help of concentrating solar thermal power technology.

Acknowledgment

Valuable suggestions made from Prof. Gopal Chaudhari, and Prof. Sharvari Sane are greatly appreciated.

ISSN: 2321-8169
146 – 151

References

[1] E. I. Ortiz-Rivera, and L. I. Feliciano-Cruz, “Performance evaluation and simulation of a solar thermal power plant,” 2009 Energy Conversion Congress and Exposition, IEEE, pp. 337344, Sept. 20-24, 2009.

[2] N. Noor, and S. Muneer, “Concentrating solar power (CSP) and its prospect in Bangladesh,” 2009 1st International Conference on the Developments in Renewable Energy Technology (ICDRET), pp. 1-5, Dec. 17-19, 2009.

[3] P. Hank, L. Eckhard, K David, Z. Eduardo, C. Gilbert, G. Randy, and M. Rod, “Advances in parabolic trough solar power technology,” Journal of Solar Energy Engineering, vol. 124, pp. 109-125, May 2002.

[4] A. Palo, “Solar thermal electric technology: 2006,” Jun. 2007.

[5] M. Jay, “Solar thermal themical review (draft report),” Feb. 2001.

[6] http://en.wikipedia.org/wiki/Solar_thermal_energy#Linear_Fresnel_refl ector_technologies (July 1st, 2011).

[7] P. J. Verlinden, A. Lewandowski, H. Kendall, S. Carter, K. Cheah, I. Varfolomeev, D. Watts, M. Volk, I. Thomas, P. Wakeman, A. Neumann, P. Gizinski, D. Modra, D. Turner, and B. Lasich, “Update on two-year performance of 120 kWp concentrator PV systems using multijunction IIIV solar cells and parabolic dish reflective optics,” 2008 Photovoltaic Specialists Conference, 33rd IEEE, pp. 1-6, May 11-16, 2008.

[8] D. Howard, and R. G. Harley, “Modeling of dish-Stirling solar thermal power generation,” Power and Energy Society General Meeting, 2010 IEEE, pp. 1-7, July 25-29, 2010.

[9] H. J. Hou, Y. P. Yang, Y. H. Cui, S. Gao, and Y. X. Pan, “Assessment of concentrating solar power prospect in China,” International Conference on Sustainable Power Generation and Supply, pp. 1-5, April 6-7, 2009.

[10] J. Aabakken, Power technologies energy date book, Fourth Edition Technical NREL/TP620-3928, August 2006.

[11] E. Zarza, L. Valenzuela, J. León, D. Weyers, M. Eickhoff, M. Eck, and K. Hennecke, “The DISS project: direct steam generation in parabolic trough systems. operation & maintenance experience and update on project status,” J. Solar Energy Eng, vol. 124, pp. 126-133, May 2002.

[12] N. Francois, F. Alain, and B. Francoise, “Thermal model of a dish/stirling systems,” Elsevier, Solar Energy, vol. 83, pp. 81-89, Jan. 2009.

[13] A. M. Al-Nasser, “Performance and economics of a solar thermal power generation plant in Jubail, Saudi Arabia: Parabolic trough collector,” Energy Conference and Exhibition (Energy Con), 2010 IEEE International, pp. 752-757, Dec. 18-22, 2010.

[14] California Energy Commission, “Beacon solar energy project,” Infrastructure Journal, April 2009.

[15] Solúcar, “10MW solar thermal power plant for southern spain,” NNE5- 1999-356, Solúcar, Spain, 2006.